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1 Attorney Docket No. 72384

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3 FLEXIBLE CABLE PROVIDING EMI SHIELDING

4

5 STATEMENT OF GOVERNMENT INTEREST

6 The invention described herein may be manufactured and used
7 by or for the government of the United States of America for
8 governmental purposes without the payment of royalties thereon or
9 therefor.

10

11 BACKGROUND OF THE INVENTION

12 (1) Field of the Invention

13 This invention relates to flexible electromagnetic
14 shielding. More specifically, the invention relates to a
15 flexible conductive material and the inclusion of appropriately
16 selected materials of high magnetic permeability. The resulting
17 compound can be extruded as part of the manufacturing process for
18 shielded cables and shielded housings for constituent cable
19 subassemblies.

20 (2) Description of the Prior Art

21 It is known in the art that sensitive electrical equipment
22 can be affected by Electro-Magnetic Interference (EMI). It is
23 also known in the art that there are several ways to reduce EMI.

24 For example, EMI can be reduced by shielding the electronic
25 equipment by enclosing it in shielded rooms and cabinets, filling

1 any gaps therein with conductive gaskets, and also by shielding
2 cables and cable assemblies connected to the electronic equipment
3 with conductive outer layers.

4 One example of EMI shielding for rooms and cabinets is
5 disclosed in U.S. Patent No. 4,992,329 which describes EMI
6 shielding in the form of a laminated sheet. The shielding effect
7 of the sheet is provided by flakes of magnetic amorphous alloy
8 that are deposited between layers of film prior to lamination.
9 Another example is U.S. Patent No. 4,965,408 which discloses
10 flexible radiation shielding in the form of a laminated sheet.
11 The EMI shielding effect of the sheet is accomplished by
12 laminating a thin metal foil between layers of a flexible outer
13 material.

14 Examples of conductive elastic gaskets are found in U.S.
15 Patent Nos. 4,948,922 and 4,937,128 which disclose conductive
16 elastic gaskets used to fill gaps between openings in shielded
17 rooms and cabinets. Both of these patents disclose the use of an
18 elastic material that is electrically conductive in and of
19 itself. Other examples are found in U.S. Patent Nos. 4,977,295,
20 4,968,854 and 4,948,922 which disclose conductive elastic gaskets
21 where the elastic material is made conductive through the
22 inclusion of the metallic particles. U.S. Patent No. 4,966,637
23 discloses a conductive elastic gasket where the requisite
24 conductivity is provided by an outer wrapping of braided wire.

1 U.S. Patent No. 4,920,233 is an example of a special purpose
2 cable which includes a concentric form of Faraday shielding, and
3 incidentally also in alternate embodiments includes a concentric
4 layer of thermoplastic material loaded with ferrite powder. The
5 purpose of that patentee's construction of cabling is to provide
6 a high fidelity music signal transmission media which features
7 consistent phase velocity characteristics over the frequency band
8 of the music, by making the distributed inductance of the cable
9 relatively large. In that patentee's embodiment of FIGS. 1 and
10 2, the distributed inductance is increased by disposing torroidal
11 ferrite sleeves 28, FIGS. 1 and 2, along the cable's axial
12 length. The function of EMI isolation is also present in that
13 patentee's embodiments of FIGS. 1, 2 and 6 therein, but in the
14 form of twisted metallic foils strips 34 (FIGS. 1 and 2) and 34A
15 (FIG. 6), and a surrounding of metallic braiding (32, FIGS. 1 and
16 2) and 32A (FIG. 6). This results in a design requiring
17 manufacture by multiple manufacturing steps employing multiple
18 types of manufacturing processes, namely, the extrusion of the
19 thermoplastic elements, and the twisting of a metallic jacket and
20 the braiding of another jacket. This multistep and multimode
21 manufacture in turn drives up direct cost of manufacture and also
22 drives up needs for investment in manufacturing machinery. In
23 another of that patentee's embodiments, FIGS. 6 and 7, the cable
24 inductance is increased by ferrite powder in an extruded
25 thermoplastic layer 26A (FIG. 6) and 48 (FIG. 7). These

1 thermoplastic layers are an electrical insulation material.
2 Thus although the ferrite particles provide inductance for
3 purposes of that patentee's invention, the insulation
4 characteristic of the thermoplastic matrix binder of their layers
5 26A (FIG. 6) and 48 (FIG. 7) would result in non-homogeneous
6 electromagnetic leakages in the spaces between the ferrite
7 particles, and would not produce the homogeneous conductivity in
8 all directions ("isotropic"), as required of a Faraday shield.
9 U.S. Patent No. 4,960,965 discloses a cable of concentric layers
10 where an outer layer of EMI shielding comprises conductive carbon
11 fibers. U.S. Patent No. 4,769,515 discloses a spirally laminated
12 cable comprising an inner metallic core and a laminated outer
13 layer including metallic foil designed to increase the surface
14 area of the metallic conductor, rather than for the purpose of
15 providing EMI protection.

16 17 SUMMARY OF THE INVENTION

18 Accordingly, it is a general purpose and object of the
19 present invention to provide a flexible cable which integrally
20 incorporates a Faraday shield for providing Electro-Magnetic
21 Interference (EMI) isolation between EMI present in the ambient
22 environment and a conductor of the cable, or vice versa.

23 Another object is to provide such a Faraday shield which
24 yields economies in its manufacture, including savings as a
25 result of need for fewer types of manufacturing machines, and

1 savings in the form of a concentric construction of less-costly-
2 to-fabricate extrudable layers.

3 This is accomplished by the present invention by using a
4 conductive elastomer as a matrix binder which is filled with
5 particles of a high permeability iron-based alloy. The
6 conductive property of the matrix binder provides isotropic
7 conductivity requisite of a Faraday shield.

8 One illustrative embodiment of a flexible cable unit
9 consists of a single conductive core having thereabout a
10 concentric Faraday EMI shielding structure in accordance with the
11 present invention. The concentric shielding structure consists of
12 a concentric pile of alternating (i) sheaths of a flexible
13 insulating material, such as rubber or polyvinyls chloride (PVC),
14 and (ii) Faraday sheaths of a high permeability ferrous alloy
15 particles loaded in a suitable conductive elastomeric matrix
16 binder material, such as CONSIL manufactured by Technical Wire
17 Products. CONSIL is an extrudeable, cure hardened material which
18 prior to extrusion includes both a flowable resin component and a
19 non-flowable component consisting of resin particles which have
20 undergone a preliminary cure and hardening cycle and are pressure
21 distortable. After the ingredients are mixed, the admixture of
22 the matrix binder and the ferrous alloy particles are extruded
23 the admixture is and cure hardened, rendering it capable of
24 providing good homogenous (isotropic) conductivity throughout the
25 material. Further details regarding this matrix binder material

1 are described in U.S. Patent No. 3,609,104 entitled "Electrically
2 Conductive Gasket and Material Thereof," specific portions of
3 which are incorporated by reference later herein in the DETAILED
4 DESCRIPTION OF THE PREFERRED EMBODIMENTS section. The sheath
5 next to the central conductive line of the cable, and the
6 outermost sheath, are of insulation materials. The loading of
7 ferrous alloy particles in the conductive set of alternating
8 sheaths is about 75% by volume, and the size of the particles is
9 10-20 grains per square inch.

10 Another illustrative embodiment is a form of what is known
11 in industry as a tri-axial cable. It consists of three
12 conductive lines subassemblies, each with a first insulating
13 sheath directly over the core and a second sheath of the
14 aforesaid conductive, elastomeric, matrix binder loaded with high
15 permeability ferrous alloy particles over the first sheath.
16 These three subassemblies sheaths are bundled and covered by five
17 alternating sets of insulator and Faraday sheaths.

18 19 BRIEF DESCRIPTION OF THE DRAWINGS

20 A more complete understanding of the invention and many of
21 the attendant advantages thereto will be readily appreciated as
22 the same becomes better understood by reference to the following
23 detailed description when considered in conjunction with the
24 accompanying drawings wherein:

1 FIG. 1 is a cross section of a concentric arrangement of a
2 central conductor, an insulator sheath and a Faraday sheath
3 useful in describing the basic concept of the invention;

4 FIG. 2 is a cross-sectional view of a flexible electrical
5 cable embodiment having plural sets of insulator and Faraday
6 sheaths in accordance with the present invention;

7 FIG. 3 is side elevation and cutaway view of the cable of
8 FIG. 2;

9 FIG. 4 is a diagrammatic representing a cross-section of a
10 triple conductive line ("triaxial cable") embodiment of the
11 flexible electrical cable in accordance with the present
12 invention; and

13 FIG. 5 is a diagrammatic representing a side elevational and
14 cutaway view of the cable of FIG. 4 (but showing only two
15 conductive line subassemblies to avoid clutter).

16 17 DESCRIPTION OF THE PREFERRED EMBODIMENT

18 Referring now to the drawings, there are shown various
19 embodiments of the flexible cables incorporating an Electro-
20 Magnetic Interference (EMI) shield, according to the present
21 invention. The function of the EMI shield of shields present in
22 these embodiments is to provide EMI isolation, or protection,
23 between the external ambient environment and the one or more
24 conductors and the cable, or vice versa. In its most basic form,
25 shown in FIG. 1, the invention may be embodied as a flexible

1 cable 10' consisting of a metal conductor core 12, surrounded by
2 an insulator sheath or layer 14, which in turn is surrounded by
3 an EMI shield sheath or layer 16. In general, electrically
4 conductive core 12 is used to transmit electrical signals and
5 power. Insulator 14 electrically isolates the conductor and the
6 EMI shield 16. The EMI shield sheath 16 protects the
7 electrically conductive core 12 against the induction thereinto
8 of EMI from ambient space, or vice versa. In a typical
9 application EMI shield sheath 16 would be grounded, but this is
10 has little bearing on broader aspects of the invention. It will
11 be appreciated that EMI shield sheath 16 constitutes what in
12 physics and electrical engineering is known as a Faraday shield.
13 It is to be understood that under the aegis of the broad concept
14 of the inventions illustrated by FIG. 1, any number of these
15 three elements can be combined to create a flexible electrical
16 cable, and the outermost layer beyond at least one EMI shield
17 sheath may be an insulator to avoid the cable presenting a short
18 circuit hazard in cabling environments which include electrically
19 "hot" terminal connectors and the like. FIGS. 2 and 3 and FIGS.
20 4 and 5 respectively show two embodiments suitable for cabling
21 applications wherein EMI isolation is particularly critical.
22 Illustrative of a cabling application wherein EMI isolation is
23 particularly critical are (i) "strapped together" expanses of a
24 plurality of data buses, and (ii) a plurality of data buses which
25 pass through tight wall penetrations. There can be situations in

1 which the introduction of EMI induced data error in one or more
2 of these data buses could cause serious equipment disruption or
3 even hazard to life. The embodiment, shown in FIGS. 2 and 3, is
4 a single flexible electrical cable 10 with a single electrically
5 conductive core 12. Another embodiment, shown in FIGS. 4 and 5,
6 is a flexible electrical cable 40 with a plurality of
7 electrically conductive cores 44. The first embodiment is used
8 when a single EMI shielded conductor is needed, and may be
9 manufactured in a continuous cable forming process. The second
10 type of cable is normally used when several conductors are to be
11 shielded, although it may also be used to just shield a single
12 conductor. While the second type of cable is normally assembled
13 as a cable assembly of specific length, it too may be
14 manufactured in continuous or near-continuous form. The
15 resulting cable may be part of organization including a larger
16 number of components such as electrical connectors (not shown)
17 attached to the ends of the cable assembly (including grounding
18 of the EMI shield sheaths 16 and 24 shown in FIGS. 2 and 3; and
19 EMI sheaths 48, 16 and 24 shown in FIGS. 4 and 5).

20 Referring now to FIGS. 2 and 3, there is shown a flexible
21 single-conductor embodiment of, multilayered EMI shielding
22 cable 10, which is generally comprised of various combinations of
23 three types of constituent elements namely: the electrically
24 conductive core 12 to be isolated, or protected; insulators 14,
25 22 and 26; and EMI shields 16 and 24.

1 Referring to FIGS. 4 and 5 there is shown a flexible,
2 multiconductor, multilayered embodiment of EMI shielding of cable
3 40 of the type frequently referred in the industry as a triaxial
4 cable. It is possible, however, for the EMI shield of the
5 present invention to be embodied in cables having fewer or more
6 layers than those shown in the drawings. The arrangement,
7 quantity, and thickness of the layers can be varied as required
8 by the end use of the cable.

9 Referring again to the single conductor embodiment of cable
10 10 (FIGS. 2 and 3), electrically conductive core 12 is generally
11 of circularily-sectioned drawn wire stock, and is made of an
12 electrically conductive material selected for its conductivity,
13 weight, compatibility and cost. Examples of such electrically
14 conductive material include copper, silver and gold.

15 A first insulator sheath 14 is concentrically disposed about
16 core 12 and surrounds and insulates the core from other
17 conductive materials. A second insulator sheath 22 constitutes
18 another insulating sheath, and a jacket 26 likewise provides
19 further electrical isolation. First insulator 14, second
20 insulator 22, and outer insulator 26 may be selected from
21 numerous flexible insulating materials based on considerations of
22 insulative properties, weight, flexibility and cost. Examples of
23 such insulators include rubber or polyvinyl chloride (PVC). Each
24 insulator can be of a different material from the other

1 insulators, each material being selected as required by the end
2 use of the cable.

3 Concentrically disposed about insulator 14 is EMI
4 shield sheath 16, where it surrounds insulator 14, as well as
5 surrounds electrically conductive core 12. Similarly, a second
6 EMI shield 24 concentrically surrounds second insulator 22 as
7 well the other layers as shown. Both first EMI shield 16 and
8 second EMI shield 24 are a high permeability metal-filled
9 conductive elastomer comprised of a conductive,
10 elastomeric, matrix binder 18 and embedded metal particles 20.
11 The preferred method of manufacturing a shield of the present
12 invention is to mix metal particles 20 with a flowable liquid
13 component that is elastomeric in its solid state, but there are
14 other methods that could be used to produce a shield of the
15 present invention.

16 Conductive elastomeric matrix binder 18 can be selected from
17 any suitable conductive elastomer based on considerations of
18 degree of conductivity, weight, flexibility and cost. One
19 example is CONSIL (manufactured by Technical Wire Products),
20 which is described in U.S. Patent No. 3,609,104 (earlier
21 identified in the SUMMARY OF INVENTION section) as an admixture
22 of a flowable component of thermosetting resin, and non-flowable
23 particles of thermosetting resin which have undergone a
24 preliminary curing and hardening phase that rendered the
25 particles pressure distortable. The high permeability ferrous

1 alloy particles are loaded in the admixture during the formation
2 of a sheath by a conventional extrusion process which also
3 performs curing and hardening of the sheath. For a more detailed
4 description of matrix binder material 18, see the aforesaid U.S.
5 Patent No. 3,609,104, the portion thereof starting at its column
6 5, line 31 through column 11, line 14 being hereby incorporated
7 herein by this reference.

8 It is to be appreciated that the term "elastomer" and its
9 adjective form "elastomeric" as used in this specification and in
10 the appended claims are intended to encompass both mixtures
11 including natural rubber material and mixtures including
12 synthetic rubbers or plastics having some of the physical
13 properties of natural rubber.

14 Metal particles 20 can be selected from numerous high
15 permeability, ferrous alloy materials similarly selected based on
16 considerations of conductivity, weight, degree of magnetic
17 permeability and cost. Insofar as the invention is presently
18 understood, the use of a conductive matrix binder to receive the
19 high permeability ferrous alloy particles contributes
20 significantly to suppression of EMI leakage paths, which is the
21 primary objective of the present invention. A specific class of
22 commercially available ferrous alloys believed effective for use
23 as particles 20 consist of: (i) 4-79 Permalloy, (ii) MUMETAL,
24 (iii) Hymu 80, (iv) 45 Permalloy, and (v) 50% nickel iron.
25 (MUMETAL is a registered trademark of Spang and Company, of

1 Butler, Pennsylvania.) One commercial source of these metals in
2 appropriate powder metal form is Carpenter Technology
3 Corporation, of Reading, Pennsylvania. The metal particles range
4 in size from approximately 10 to 20 grains per square millimeter.

5 The conductive elastomer with which these metal particles
6 are composited in order to form an extrudable composition is the
7 matrix binder material in which the particle are loaded. For
8 purposes of the invention, the higher the percentage of metal
9 particles, the more effective layers 16, 24 and 48 are in
10 providing the electromagnetic shielding function. One embodiment
11 of invention employs a composition in which the percentage, by
12 volume, of the metal particles in the composition is seventy-five
13 percent (75%).

14 While it is possible for the components of the embodiment to
15 be manufactured separately and then assembled to form a completed
16 cable, the preferred method of manufacturing the single conductor
17 embodiment of FIGS. 2 and 3 is to make a cable as a single unit
18 by extruding the concentric pile of sheaths or layers about the
19 conductor. The resulting flexible electrical cable 10 has a
20 central axis corresponding to the middle of core 12.

21 Referring again to the multiple-conduction line type of
22 cable 40, FIGS. 4 and 5, a set of outer extra-conductor-line-
23 subassembly-sheaths 41 surrounds and isolates, or protects, one
24 or more inner-conductor-line-subassemblies 42 containing
25 individual conduction lines. The particular multiconductive,

1 multilayered cable depicted therein has a conduction core
2 comprised of three individual conductor line cables, or
3 conductor-line-subassemblies 42, and is of the type frequently
4 referred to in the industry as a "triaxial cable". Each
5 conduction line cable 42 is a subassembly of cable 40. It is
6 possible, however, for the present invention to be embodied in
7 the form of cables having fewer or more layers and fewer or more
8 inner cables than those shown in the drawings. The arrangement,
9 quantity, design and thickness of the layers and inner cables can
10 be varied as required by the end use of the design cable. A set
11 of outer, or extra-conductor-line-subassembly, Faradays sheaths
12 41 is generally comprised of various combinations of sets of an
13 extra-conductor-line-subassembly insulator and an extra-
14 conductor-line-subassembly Faraday shield sheaths, namely:
15 insulator 14, 22, and 26; and Faraday shields 16 and 24. These
16 components serve the same purposes as the corresponding
17 components discussed in connection with the single-conductor
18 cable of FIGS. 2 and 3.

19 Each individual conduction line cables 42 is generally
20 comprised of various combinations of three components: an inner
21 electrical conductor or core 44, a sheath or layer of insulating
22 material 46, and a layer of high-permeability-ferrous-alloy-
23 particle-filled-conductive, elastomeric matrix binder 48. While
24 it is possible for the components of the set of extra subassembly
25 sheaths 41 to be manufactured separately and then assembled to

1 form a complete housing, the preferred method of manufacturing a
2 set of sheaths 41 is by extruding the appropriate sheaths layers
3 sheaths or as a generally concentric pile of sheaths having a
4 nominal central axis disposed at the center of the bundle of
5 cables 42.

6 The number and construction of each inner cable 42 may vary
7 depending on the anticipated end use of the cable. In fact, a
8 flexible electrical cable 10, FIGS. 2 and 3, can be used as an
9 inner cable 42.

10 It is to be appreciated that an important aspect of the
11 present invention is the discovery, or inventive appreciation,
12 that the utilization of a matrix binder material that has the
13 property of being a conductive material yields the desired effect
14 of substantially isotropic conductivity within Faraday shield
15 sheaths 16 (FIGS. 1, 2, 3, 4 and 5), 24 (FIGS. 2, 3, 4 and 5),
16 and 48 (FIG. 5), which is a necessary characteristic of an
17 effective Faraday shield.

18 Obviously, many modifications and variations of the present
19 invention may become apparent in light of the above teachings.
20 For example, while the above description has emphasized the
21 function of high permeance, ferrous alloy-filled, elastomeric
22 conductive matrix binder sheaths 16 (FIGS. 1, 2, 3, 4 and 5), 24
23 (FIGS. 2, 3, 4 and 5), and 48 (FIG. 5) as EMI shielding, it will
24 be appreciated that there may be a design requirement for the
25 cable to provide additional conductive paths for signals or

1 power, and any or all of the matrix binder sheaths may serve the
2 additional function of providing these paths. It is therefore to
3 be understood that , the
4 invention may be practiced otherwise than as specifically
5 described.

1 Attorney Docket No. 72384

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3 FLEXIBLE CABLE PROVIDING EMI SHIELDING

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5 ABSTRACT OF THE DISCLOSURE

6 A flexible cable which includes a Faraday shield sheath
7 formed of a high permeability ferrous alloy filled matrix binder
8 of conductive elastomer, to provide electromagnetic interference
9 (EMI) isolation between the ambient environment about the cable
10 and a conductor line or lines within the cable, or vice versa.
11 The flexible cable shield may be embodied as a flexible
12 electrical cable that comprises at least the elements of a single
13 electrically conductive core, an insulator sheath, and a Faraday
14 shield sheath, and may be manufactured as a single extruded
15 cable. The conductive property of the matrix binder provides
16 isotropic conductivity within the sheath, which is requisite of
17 an effective Faraday shield. In the alternative, the flexible
18 cable shield may be embodied as a multiple conductor flexible
19 electrical cable that comprises two or more inner cables as
20 described, and a pile of alternating insulator and a Faraday
21 shield sheaths about the inner cables.

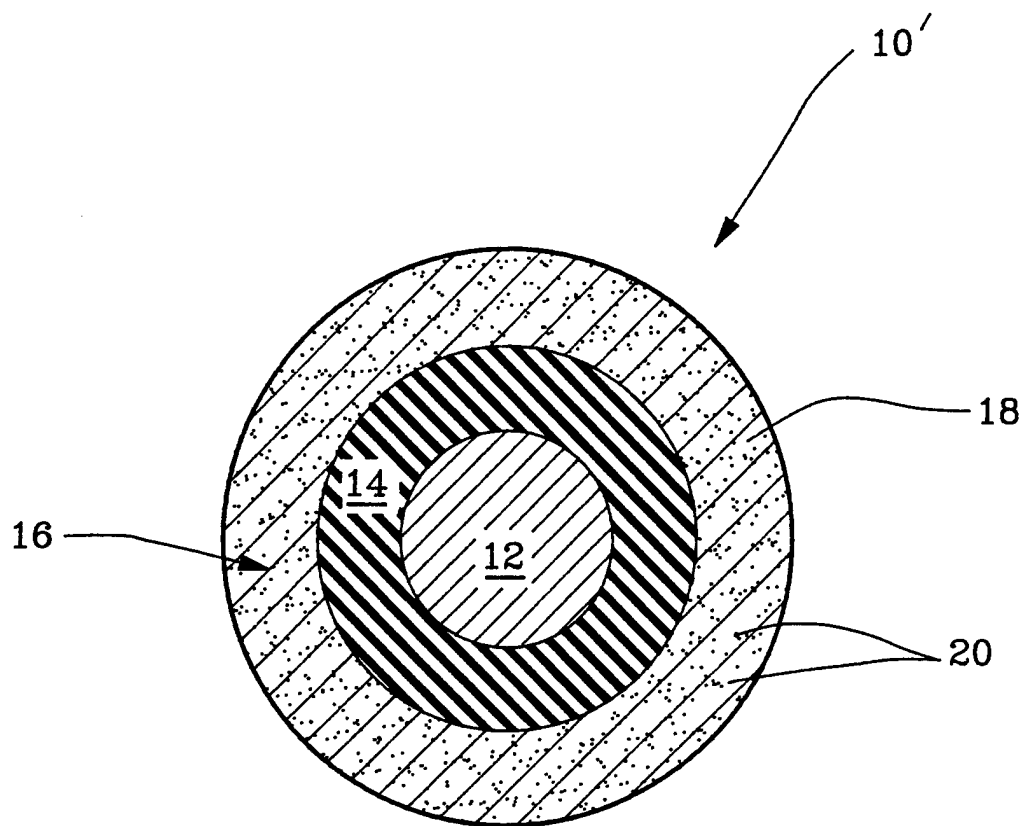


FIG. 1

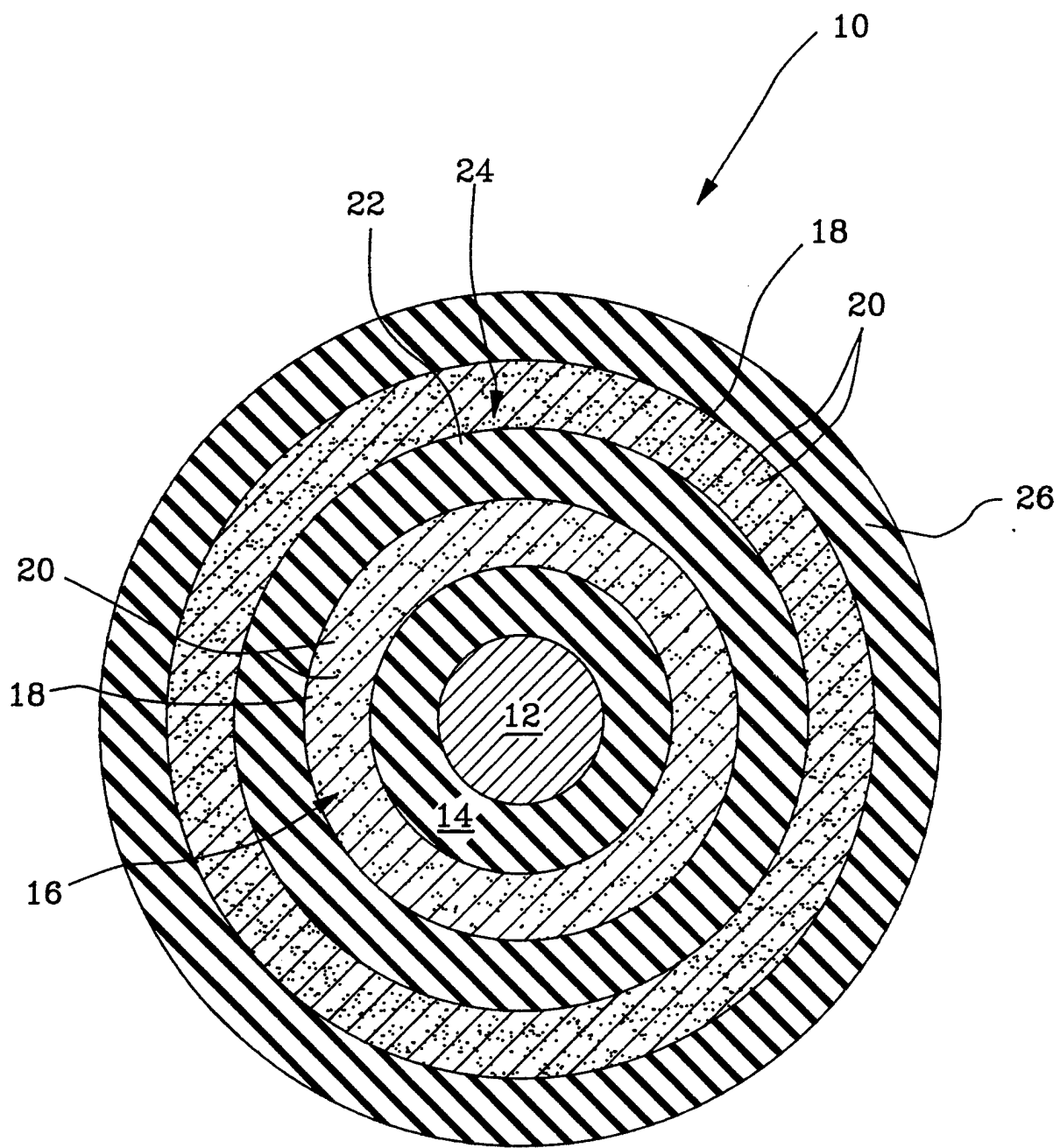


FIG. 2

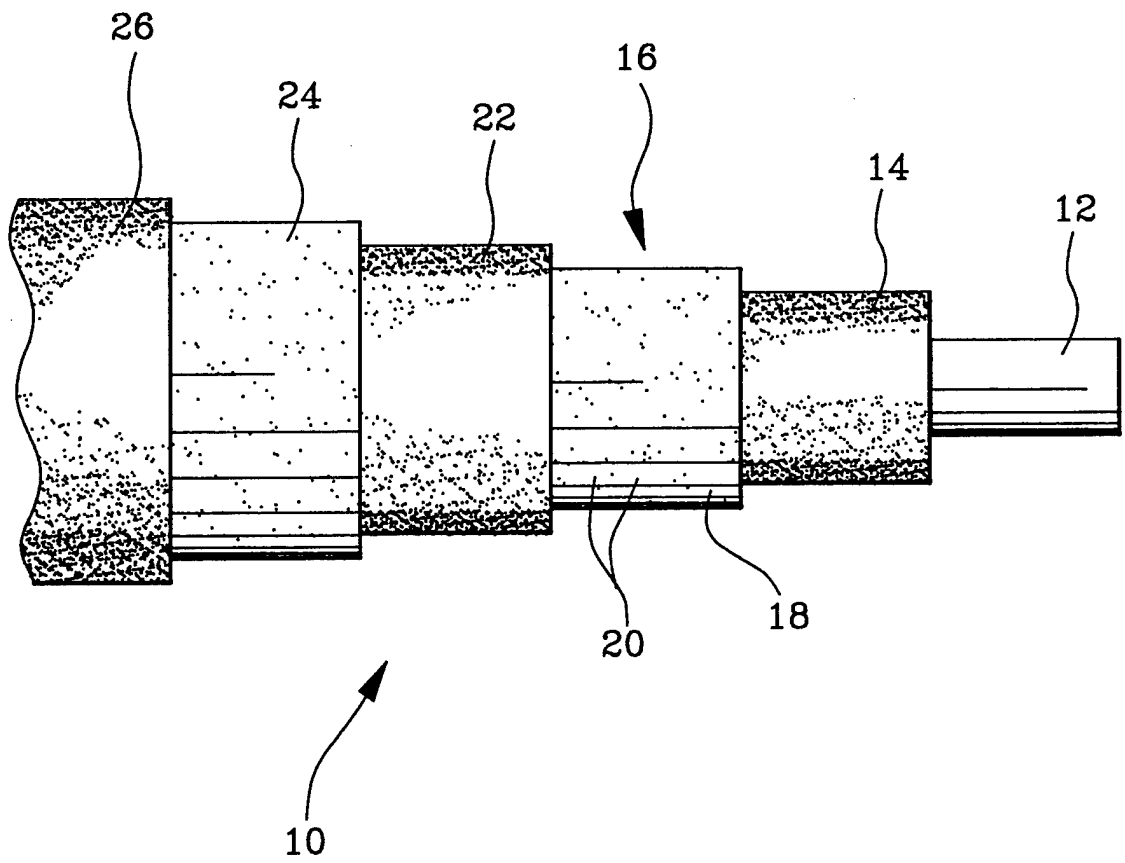


FIG. 3

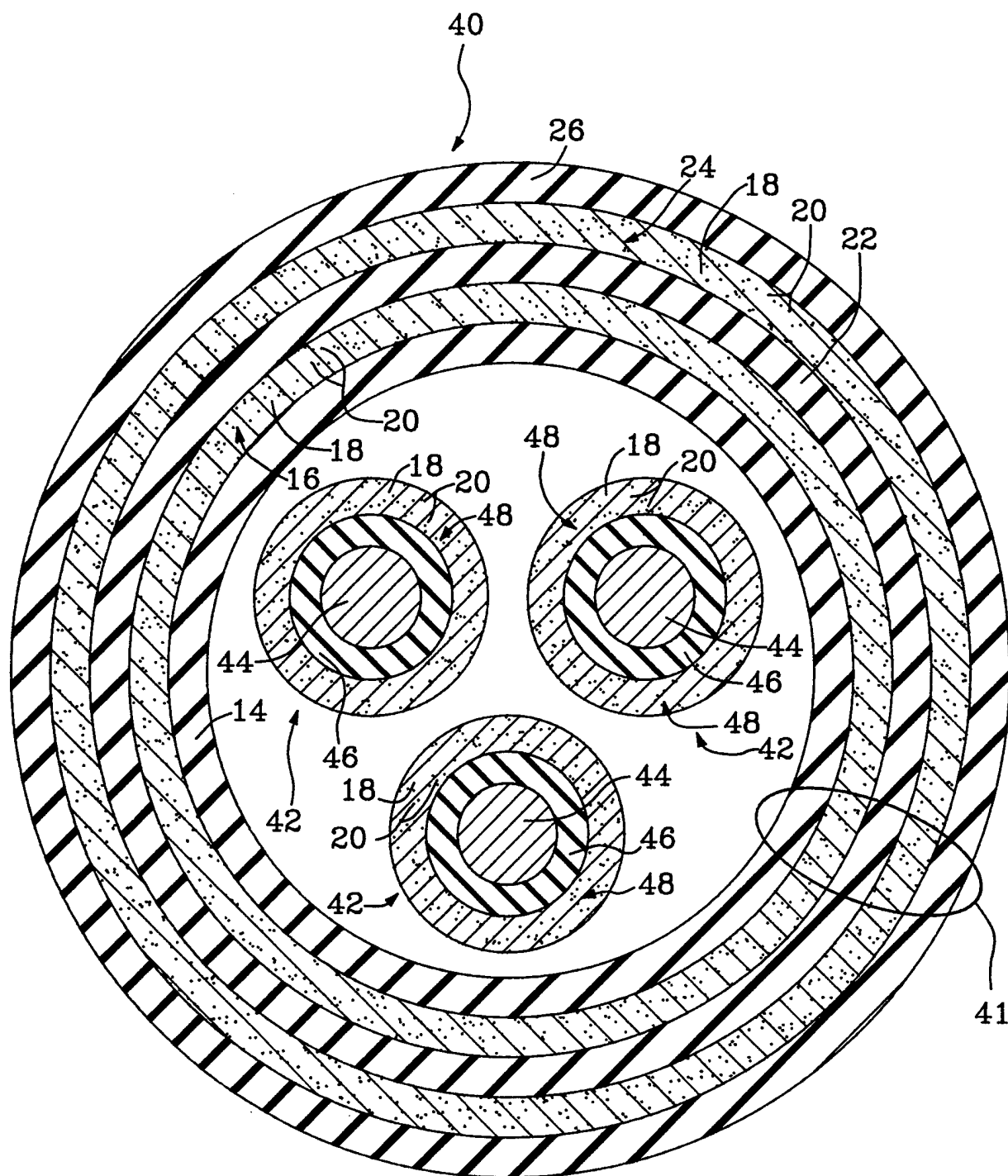


FIG. 4

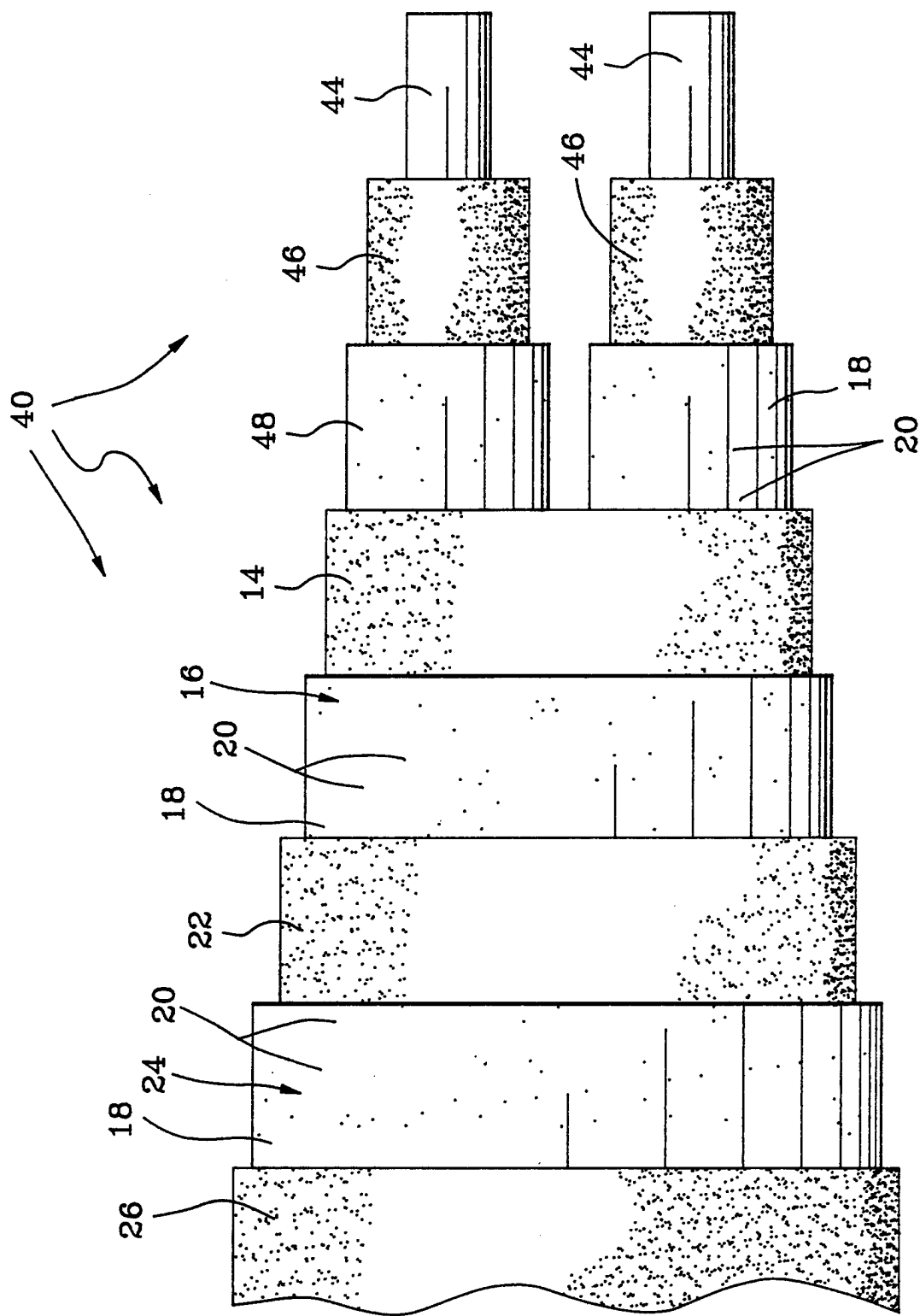


FIG. 5